

V723 CASSIOPEIA STILL ON IN X-RAYS: A BRIGHT SUPER SOFT SOURCE 12 YEARS AFTER OUTBURST

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ABSTRACT

We find that the classical nova V723 Cas (1995) is still an active X-ray source more than 12 years after outburst and analyze seven X-ray observations carried out with *Swift* between 2006 January 31 and 2007 December 3. The average count rate is 0.022 ± 0.01 cts s⁻¹ but the source is variable within a factor of two of the mean and does not show any signs of turning off. We present supporting optical observations which show that between 2001 and 2006 an underlying hot source was present with steadily increasing temperature. In order to confirm that the X-ray emission is from V723 Cas, we extract a *ROSAT* observation taken in 1990 and find that there was no X-ray source at the position of the nova. The *Swift* XRT spectra resemble those of the Super Soft X-ray binary Sources (SSS) which is confirmed by *RXTE* survey data which show no X-ray emission above 2 keV between 1996 and 2007. Using blackbody fits we constrain the effective temperature to between $T_{\text{eff}} = (2.8 - 3.8) \times 10^5$ K and a bolometric luminosity $\gtrsim 5 \times 10^{36}$ erg s⁻¹ and caution that luminosities from blackbodies are generally overestimated and temperatures underestimated. We discuss a number of possible explanations for the continuing X-ray activity, including the intriguing possibility of steady hydrogen burning due to renewed accretion.

Subject headings: stars: novae, stars: individual: V723 Cas

1. INTRODUCTION

Classical Novae (CNe) are the observable events caused by thermonuclear runaways on the surfaces of white dwarfs (WDs), fueled by material accreted from a companion star. Material dredged up from below the WD surface is mixed with the accreted material and violently ejected. The outburst continues until either nuclear burning has converted all the remaining hydrogen on the WD surface to helium or it has been ejected from off the WD. The bolometric luminosity at the peak of the explosion is near or exceeds the Eddington luminosity, $\sim 1 \times 10^{38}$ erg s⁻¹ for a 1-M_⊙ WD (see for example Schwarz et al. 2001). Initially, the radiative energy output of the nova peaks in the optical, since the binary is surrounded by expanding ejecta that are not transparent to the high-energy radiation produced on the surface of the WD by nuclear burning. As the ejecta expand and thin (and the remaining material on the WD burns hydrostatically in a shell), the photosphere

recedes to inner and hotter layers. The peak of the spectral energy distribution then shifts to higher energies (Gallagher & Starrfield 1978).

The X-ray bright phase of the evolution has only been observed sporadically, with the first systematic observations obtained with *ROSAT* (e.g., Krautter 2002). The X-ray spectrum during this phase was found to sometimes resemble that of the class of Super Soft X-ray Binary Sources (SSS; van den Heuvel et al. 1992) such as Cal 83 in the LMC (e.g., Lanz et al. 2005). This phase is now called the SSS phase. V1974 Cyg was the first nova to be followed in X-rays from before the SSS phase until decline. Krautter et al. (1996) reported a slow rise and fast decline of the X-ray brightness after the peak had been reached. The first spectral modeling of V1974 Cyg was carried out by Krautter et al. (1996) using blackbody fits, but Balman et al. (1998) reanalyzed the spectra using LTE atmosphere models, because blackbodies did not fit the spectra. It is further known that luminosities and temperatures derived from blackbody fits are inconsistent with realistic physical conditions, with a tendency to overestimate the luminosity and thus underestimate the temperature (Kahabka & van den Heuvel 1997). The LTE models presented by Balman et al. (1998) were an attempt to account for complex absorption patterns that change the shape of the spectrum. Although only 24 spectral bins were available, an attempt was made to determine a large number of parameters (temperature, surface gravity, bolometric luminosity, neutral hydrogen column density, and the abundances of carbon, oxygen, and neon). Further, LTE and a static WD atmosphere were assumed. The combination of a small ratio of independent data points to adjustable parameters and the limitations of current atmosphere models call for caution when drawing conclusions from these models. The effects of the expansion, especially during the early phases of the evolution, have been investigated with the PHOENIX code by Petz et al. (2005).

In addition to the SSS spectrum Krautter et al. (1996) found a hard component that was fit with a MEKAL model by Balman et al. (1998) and thus was assumed to be an optically thin

TABLE 1
JOURNAL OF OPTICAL OBSERVATIONS

Date	UT Time (hh:mm:ss)	t_{exp} (s)	Obs. ^a	[Fe X]/[Fe VII] ^b
2001 Jan 19	03:57:21	300	SO 90"	0.02
2003 Sep 13	09:39:37	600	MMT	0.62
2004 Jun 26	10:17:09	600	SO 90"	0.81
2006 Nov 9	02:42:59	600	SO 90"	2.33

^a Steward Observatory Bok 90 inch telescope and the Multiple Mirror Telescope. ^b Ratio of the [Fe X] (6373Å) to [Fe VII] (6087Å) lines.

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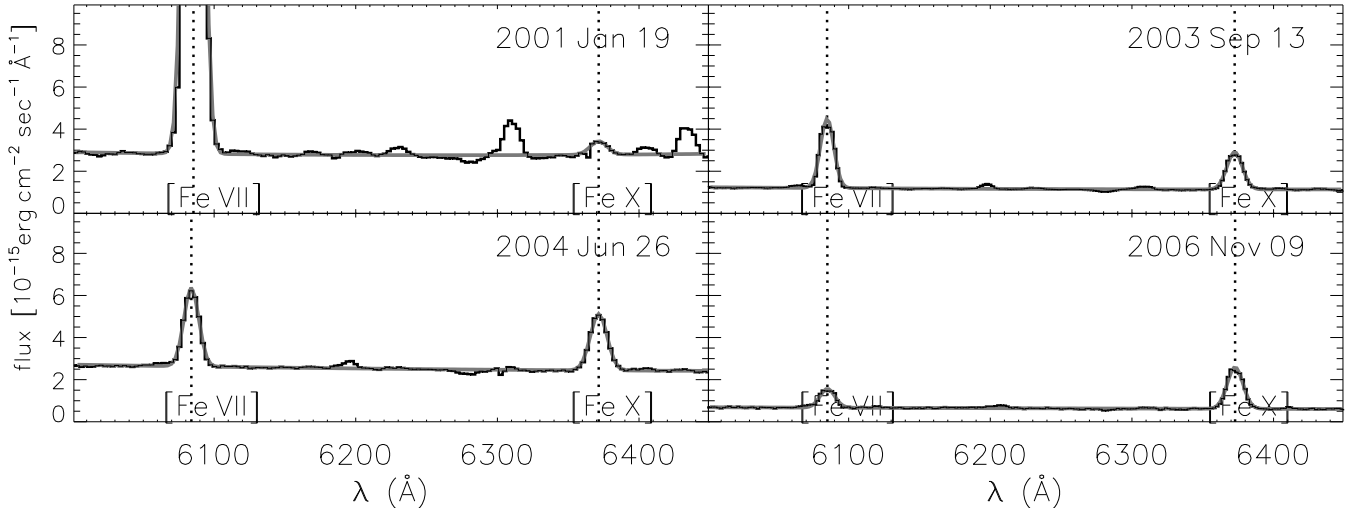


FIG. 1.— Optical spectra of V723 Cas taken between January 2001 and November 2006, focusing on the [Fe X] and [Fe VII] emission lines at 6376 Å and 6089 Å, respectively (see Table 1). The ratio of these lines is continuously increasing, suggesting that there is a hot source ionizing increasingly tenuous ejecta.

plasma that is radiatively cooling. This phenomenon has been observed in a number of novae (e.g., Ness et al. 2007a), the most recent example being RS Oph (e.g., Ness et al. 2007b).

A systematic search of all *ROSAT* observations of novae including the *ROSAT* All Sky Survey and the archives of pointed *ROSAT* observations was carried out by Orio et al. (2001). Of a sample of 108 CNe and recurrent novae (RNe) that exploded within the last ~ 100 years, very few SSS spectra were found implying that the SSS phase must be short. A recent survey of all novae observed with *Swift* also resulted in few detections of CNe in the SSS phase (e.g., Ness et al. 2007a). Few Galactic (e.g., Orio et al. 2001; Ness et al. 2007a and references therein) and extra-galactic (Pietsch et al. 2005, 2007) novae have had the duration of this phase determined. In the extra-galactic surveys candidates for novae in the SSS phase can be confused with supernova remnants, foreground neutron stars, or black hole transients (Orio 2006).

SSSs are believed to be WDs with accretion rates high enough to sustain steady nuclear burning (van den Heuvel et al. 1992; Kahabka & van den Heuvel 1997). Stable shell burning can cause the WD to grow in mass via accretion with a buildup of hydrogen deficient material. Thus, the SSSs are strong candidates for single-degenerate supernovae Ia (SN Ia) progenitors (Starrfield et al. 2004). In general, CNe are not considered to be SN Ia progenitors because the outburst is believed to eject more material than is accreted.

While theoretical models predict novae to be active for 10s to 100s of years (e.g., Starrfield 1989; Sala & Hernanz 2005), all novae observed so far in X-rays have turned off after much less than a decade (Orio et al. 2001; Ness et al. 2007a), implying mass must be lost during the outburst by some mechanism (e.g., MacDonald et al. 1985). The typical observed outburst duration is of order one year with the longest observed Galactic nova in outburst being GQ Mus at ~ 9 years (Ögelman et al. 1993; Shanley et al. 1995). The outburst duration depends on the nuclear burning rate, the amount of hydrogen left on the WD after the explosion, and the rate of any ongoing mass loss. Unfortunately, all these properties including the WD mass, the most critical driver, are poorly known.

A different approach was proposed by Greiner et al. (2003) who found from the available data that systems with shorter orbital periods display long durations of supersoft X-ray phases, while long-period systems show very short or no SSS phase at all. They speculate that shorter periods may be re-

lated to a higher mass transfer rate (e.g., by increased irradiation) and thus to the amount of material accreted before the explosion.

In this paper we present *Swift* observations in X-rays of the slow nova V723 Cas (§2). In §3 & §4 we describe the observations and our analysis and address the possible future X-ray evolution in §5.

2. V723 CAS BACKGROUND

V723 Cas was discovered on 1995 August 24 (Hirose et al. 1995), and reached visual maximum on 1995 December 17 at 7.1 mag (Munari et al. 1996). Its pre-2001 evolution has been extensively observed from ultraviolet (Gonzalez-Riestra et al. 1996) to radio (Heywood et al. 2005) wavelengths. A detailed description of the optical photometric evolution since 2001 is given by Goranskij et al. (2007, and references therein). The orbital period is ~ 16.6 hours with a sinusoidal-like shape of the V-band variations (Goranskij et al. 2007).

We have monitored the optical spectral evolution of V723 Cas since the outburst. Beginning in 2001, V723 Cas evolved to an extreme "coronal" phase with the emergence of the high ionization line of [Fe X] $\lambda 6376$ Å (Fig. 1; see also Iijima 2006). This iron line was also strong in the late-time spectra of GQ Mus (Krautter & Williams 1989; Ögelman et al. 1993) which was observed by *ROSAT* to have a SSS X-ray spectrum. In Fig. 1 we show the development of [Fe X] relative to [Fe VII] $\lambda 6089$ Å, between January 2001 and November 2006 in V723 Cas (see Table 2; for details on the observations we refer to Schwarz et al. in preparation). By 2006 the [Fe X] line flux exceeded that of [Fe VII] indicating that the ejecta were being photoionized by a hot ($> 2 \times 10^5$ K) central source, implying ongoing nuclear burning on the WD (see also Greenhouse et al. 1990). The [Fe X] and [Fe VII] lines can be used to monitor the temporal evolution of the photoionizing X-ray source and constrain the turn-off timescale. The spectral similarity of V723 Cas to GQ Mus motivated our initial *Swift* X-ray observation. Further analysis of the optical spectra, along with data from other wavelengths, will appear in an upcoming paper.

2.1. Extinction and Distance determinations

Determining the X-ray luminosity requires knowledge of the extinction and distance to V723 Cas. The HEASARC N_H

TABLE 2
Swift XRT OBSERVATIONS

Date	ObsID	t_{exp} (s)	10^{-3} cts s^{-1}	hardness
2006 Jan 31.3	00030361001	6840	26.3 ± 2.2	-0.10 ± 0.09
2006 July ^a	0003036100 ^a	8650	14.0 ± 1.0	0.11 ± 0.13
2006 Sep 30.4	00030361008	5750	30.1 ± 2.5	-0.08 ± 0.10
2007 Jan 31.0	00030361010	900	49.2 ± 8.7	0.06 ± 0.24
2007 Feb 06.8	00030361011	1970	29.9 ± 4.5	-0.08 ± 0.17
2007 Nov 18.6	00030361012	3800	21.7 ± 2.7	0.13 ± 0.18
2007 Dec 03.3	00030361013	3600	35.0 ± 3.4	0.31 ± 0.17

^a Four observations between July 9.1 and July 14.7, ObsIDs 0003036100[3,5,6,7]

tool⁶ calculates the total Galactic H I column density for any direction using the Leiden/Argentine/Bonn (LAB; Kalberla et al. 2005) and Dickey & Lockman (1990) Galactic H I surveys. For a cone of radius 0.5° centered on the J(2000) coordinates of V723 Cas, the LAB and Dickey & Lockman (1990) maps give average N_{H} values of $2.2 \times 10^{21} \text{ cm}^{-2}$ and $2.5 \times 10^{21} \text{ cm}^{-2}$, respectively. Since there is a possibility of circumstellar hydrogen from either the ejecta or more recent mass loss, direct measurements of extinction are warranted. We use estimates of $E(B-V)$ from optical and UV data to derive N_{H} . Chochol & Pribulla (1997) found $E(B-V)$ of $\simeq 0.59$ and $\simeq 0.54$ from the observed versus intrinsic (B-V) values at maximum and 2 magnitudes after maximum. Munari et al. (1996) estimated $E(B-V) \simeq 0.45$ from a fit to the early interstellar Na I D absorption lines, while the Schlegel et al. (1998) extinction maps give an $E(B-V)$ of $\simeq 0.4$ for the V723 Cas location. The 2175\AA feature in the UV gives another direct measurement of $E(B-V)$. Early IUE observations, while the source was still optically thick, indicated $E(B-V) = 0.6$ (Gonzalez-Riestra et al. 1996) while a recent *Galax* observation implies a slightly lower value of 0.5 (Schwarz et al. 2007a). All methods are consistent with $E(B-V) = 0.5 \pm 0.1$. Converting to N_{H} using the relation $< N_{\text{H}}/E(B-V) > = 6 \pm 2 \times 10^{21} \text{ cm}^{-2}$ (Dickey & Lockman 1990; Bohlin et al. 1978) constrains N_{H} to values between $1.6 \times 10^{21} \text{ cm}^{-2}$ and $4.8 \times 10^{21} \text{ cm}^{-2}$ which is consistent with the Galactic H I column density maps.

There are three distance estimates in the literature. Heywood et al. (2005) used model fits to the radio light curve to obtain $d = 2.4 \pm 0.4 \text{ kpc}$. Iijima et al. (1998) estimated a distance of 2.95 kpc from the strength of the interstellar Na I D absorption lines in the early spectra while Iijima (2006) applied a maximum magnitude versus rate of decline (MMRD) relationship to the smoothed light curve for a distance of 2.8 kpc. Since the early light curve of V723 Cas was extremely irregular, the MMRD method is problematic (see also Schwarz et al. 2007b). Another approach is to assume that novae with similar characteristics, e.g., light curve evolution, ejection velocities, etc., have the same absolute magnitudes at maximum. For V723 Cas we use the similar slow nova, HR Del, which has an accurate distance estimate from expansion parallax measurements of its ejecta (Harman & O'Brien 2003). The distance from this assumption, allowing for the uncertainty in the reddening given above, is $2.7^{+0.4}_{-0.3} \text{ kpc}$. All four estimates are consistent and thus we adopt $d = 2.7 \text{ kpc}$ for the rest of the paper.

3. OBSERVATIONS

⁶ <http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/w3nh/w3nh.pl>

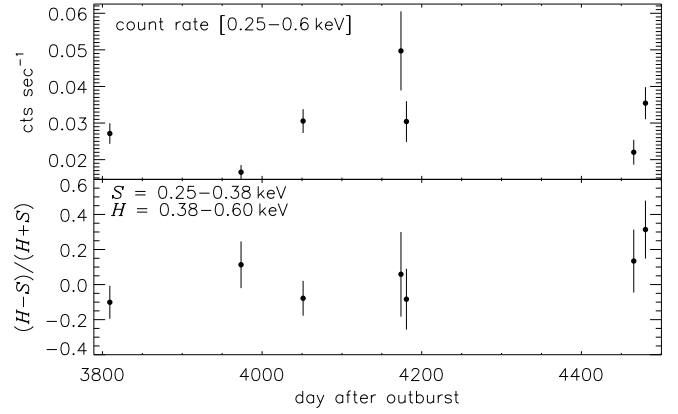


FIG. 2.— Count rates (top) and hardness ratios (bottom) as a function of time (day after outburst).

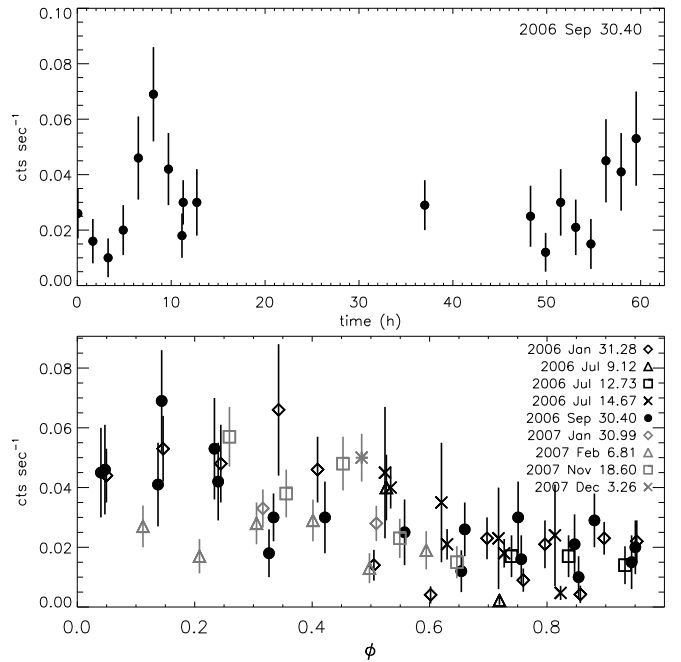


FIG. 3.— **Top:** Light curve for ObsID 00030361008, extracted from 0.25–10 keV. The observation consists of 19 observation intervals (OBIs) and considerable variability can be identified. **Bottom:** Average count rates extracted from all OBIs and plotted versus orbital phase ($\phi = 0$ marks optical minimum; ephemeris taken from Goranskij et al. 2007).

The first observation with the *Swift* X-Ray Telescope (XRT; Burrows et al. 2005) of V723 Cas was taken on 2006 January 31.27 and yielded a clear detection with no counts above 0.6 keV and a peak at $\sim 0.35 \text{ keV}$, thus typical of a SSS spectrum (Ness et al. 2006, 2007a). We have obtained six more *Swift* observations on the dates listed in Table 2, and the mean count rate for all observations is $0.022 \pm 0.01 \text{ cts s}^{-1}$. In this table we also list the ObsIDs, exposure times, measured count rates and spectral hardness ratios, $HR = (H - S)/(H + S)$ with S and H denoting the count rates in the energy ranges 0.25–0.38 keV and 0.38–0.60 keV, respectively. The extraction of count rates and spectra is described in Ness et al. (2007a). Briefly, we use a circular extraction region with radius 10 pixels for the source and an annular extraction region with inner radius 10 pixels and outer radius 100 pixels for the background. The extracted count rates are independent of the size of the extraction region. In Fig. 2 we show the evolution of count rate and hardness ratio with time. While the count rate

varies by over a factor of two from the mean, no changes of the hardness ratio can be established at a significant level (see also Table 2).

Due to the orbit of the space craft, only short continuous observations (snapshots) can be taken. Each observation consists of between 1 and 20 short snapshots separated by hours to days. We extracted the count rates for each snapshot individually and show the evolution of count rate for ObsID 00030361008 in the top panel of Fig. 3. During the first part of the observation a flare with an amplitude of a factor three above the pre-flare and post-flare rates can be seen. The other observations also show considerable variability. In the bottom panel of Fig. 3 we show all observed count rates as a function of orbital phase, which was computed based on the ephemerides given by Goranskij et al. (2007). While the count rates between phase $\phi = 0$ and 0.5 appear to be slightly higher, there is no systematic trend with phase in this dataset.

Next we extracted spectra for each observation and found all to be typical SSS spectra. Since the hardness ratio doesn't change at a significant level, no significant difference between model parameters related to the spectral shape (e.g., temperature) can be expected, and we combined all observations into a single spectrum (31.4 ksec) for the spectral analysis (see Fig. 4).

V723 Cas was also detected in the *XMM-Newton* Slew Survey Full Source Catalog (v1.1, Read et al. 2005) in an observation taken on 2007 February 1 (22:33:51 start time; ObsID 9130900003) with a count rate of 1.2 cts s^{-1} . We converted this count rate to an equivalent *Swift* XRT rate using the HEASARC tool *PIMMS*, assuming a blackbody spectrum with $kT = 30 \text{ eV}$, and the converted value is consistent with our contemporaneous observations. There is no detection in the hard energy band, defined as 2–12 keV.

As a confirmation that the *Swift* X-ray source is associated with the 1995 outburst of V723 Cas, we inspected the *ROSAT* archive for any observations prior to August 1995 near the coordinates of V723 Cas. We found one match, an observation on 1990 July 30 (ObsID 930702) from which we determine an upper limit of $4.4 \times 10^{-4} \text{ cts s}^{-1}$ at the coordinates of V723 Cas. Converting the mean *Swift* count rate to *ROSAT* counts with *PIMMS*, results in an expected *ROSAT* count rate ≈ 1000 times brighter than the measured upper limit. Thus we conclude that there was no X-ray source at this position prior to the 1995 outburst and that the current *Swift* observations are associated with the 1995 outburst of V723 Cas.

V723 Cas was included in the survey of *RXTE* All-Sky Monitor Long-Term Observed Sources. Between 1996 January 4 and 2007 September 20, 75691 observations were taken in the energy band between 2 and 12 keV with exposure times between 11 and 92 seconds. Out of this sample there are 30 detections at a significance level $> 3\sigma$ and five at $> 4\sigma$, with no systematic trend in time. Meanwhile, there are 2793 observations where the background-subtracted count rate is below zero at the $> 3\sigma$ significance level, and five events have negative count rates at a 4σ significance level. We conclude that none of these observations deliver convincing detections of the source in hard X-rays. This assertion is consistent with the non-detection of V723 Cas in the 2–12-keV band of the *XMM-Newton* observation and with our soft *Swift* spectra yielding no signal above 0.6 keV (Fig. 4).

4. ANALYSIS

Given the relatively modest spectral resolution of the XRT, we utilized blackbody fits, $B_\lambda(T_{\text{eff}})$, to determine the range of

temperature consistent with the observed spectrum. We took the temperatures, T_{eff} , and the emitting radii, R_{EM} (derived from the normalization assuming a distance of $d = 2.7 \text{ kpc}$), to determine bolometric luminosities, L_{bol} . We corrected for interstellar absorption by fitting a parameterized bound-free absorption model implemented in *PINTofAle* (Kashyap & Drake 2000). The total column density from free-bound absorption by neutral elements in the line of sight was computed from the hydrogen column density, N_{H} , assuming solar abundances. In an iterative process we determined the combination of the three parameters T_{eff} , R_{EM} , and N_{H} that yielded the best agreement with the measured spectrum, using a maximum likelihood estimator. We determined uncertainties of the parameters by application of the likelihood ratio test, i.e., we consider two models to be different with probabilities 68.3%, 84.3%, 95.45%, and 99% if the likelihood, increases by 3.53, 6.25, 8.02, and 11.3, respectively, from the lowest of all likelihood values (for three free parameters). We carried out rigorous optimization of all three parameters, but found an unrealistically high value of luminosity and a value of N_{H} that is inconsistent with the *Galex* observations (§2.1). We therefore explore the full uncertainty range and constrain the range of solutions within these uncertainties plus physical arguments.

In Fig. 4 we compare four fits with fixed $N_{\text{H}} = (6.0, 4.8, 4.0, 1.6) \times 10^{21} \text{ cm}^{-2}$ but fitted T_{eff} and R_{EM} and find the values listed in the legend. In the bottom right we show the likelihood values compared to the fit with the lowest likelihood. It can be seen that better fits are achieved with values of N_{H} greater than the upper bound found from the *Galex* observations (see §2.1). However, the likelihood for the fit with $N_{\text{H}} = 4.8 \times 10^{21} \text{ cm}^{-2}$ increases by less than 3.53 in value and is thus consistent within 68.3 per cent probability. In addition to statistical arguments from the spectral fitting, physical arguments must be considered. For example, the fit with $N_{\text{H}} = 1.6 \times 10^{21} \text{ cm}^{-2}$ gives a radius that is too small for a WD, while the fit with $N_{\text{H}} = 6.0 \times 10^{21} \text{ cm}^{-2}$ is too luminous. The super-Eddington luminosity phase in novae is extremely short, lasting at best days and certainly not over 12 years (Schwarz et al. 2001).

In Fig. 5 we show the results from computing a grid of models as a contour plot with the confidence intervals from the likelihood ratio test shown in shades of gray. Overplotted are the contours of the upper and lower N_{H} values derived in §2.1 and contours of emitting radii. The R_{EM} values can be interpreted as a proxy of the WD mass. A static $1\text{-}M_{\odot}$ WD has a radius of $\sim 6,000 \text{ km}$ (e.g., Sirius B; Barstow et al. 2005). WDs with a lower mass will have a larger radius, or the radius can be larger as a result of surface hydrogen burning.

A $1.4\text{-}M_{\odot}$ WD has a radius of $\sim 2000 \text{ km}$ (computed from eq. 3 in Truran & Livio 1986), and no radii below $R_{\text{EM}} = 2,000 \text{ km}$ are physically realistic. We also have to exclude luminosities above the Eddington limit, which is $\sim 2 \times 10^{38} \text{ erg s}^{-1}$ for a $1\text{-}M_{\odot}$ WD. The most likely region in the luminosity- T_{eff} diagram shown in Fig. 5 is therefore the $3\text{-}\sigma$ contour area, bounded by the $N_{\text{H}} = 4.8 \times 10^{21} \text{ cm}^{-2}$ contour on the left and top. From Fig. 5 it is apparent that this boundary also excludes the physically unrealistic luminosities above $\log(L_{\text{bol}}) = 38.3$. Meanwhile, the lower bound of $1.6 \times 10^{21} \text{ cm}^{-2}$ is less likely, according to our fits than the higher value of $N_{\text{H}} = 4.8 \times 10^{21} \text{ cm}^{-2}$. With these boundaries, we find a range in $T_{\text{eff}} \sim (2.8\text{--}3.8) \times 10^5 \text{ K}$ and L_{bol} greater than $5 \times 10^{36} \text{ erg s}^{-1}$, but less than $2 \times 10^{38} \text{ erg s}^{-1}$. Within these uncertainties and those in the distance, the derived V band magnitude from the range of blackbody fits is consistent

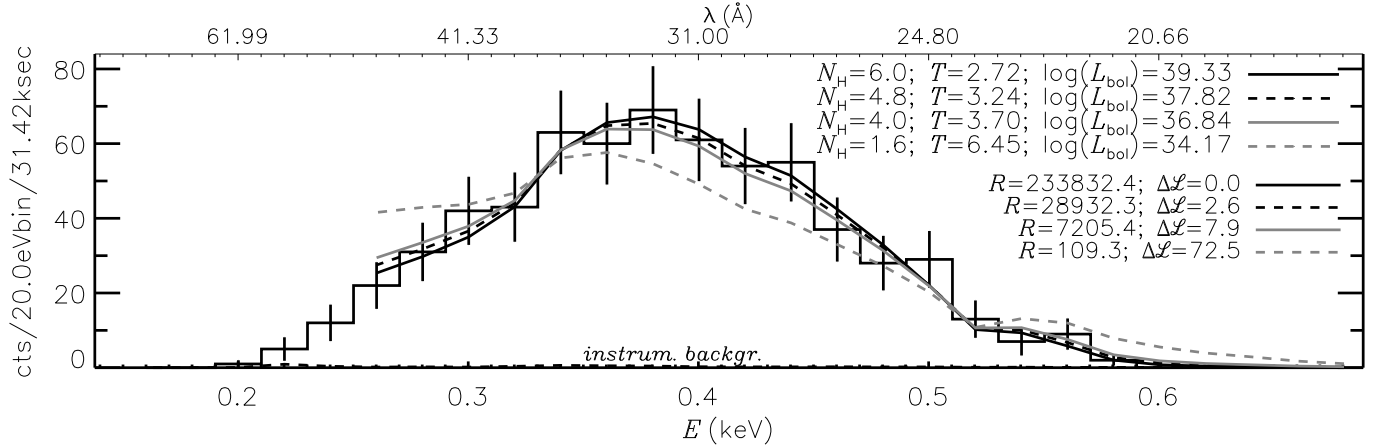


FIG. 4.— Blackbody fits to the combined XRT spectrum (rebinned by a factor of two). Spectral bins below 0.25 keV were excluded from the fit because of uncertain XRT calibration. We tested four different values of the hydrogen column density, N_H (given in 10^{21} cm^{-2}), and optimized the effective temperature (T given in 10^5 K) and bolometric luminosity ($\log L_{\text{bol}}$ in erg s^{-1}). Emitting radii, R , are given in km. The values of $\Delta\mathcal{L}$ in the legend indicate the change in likelihood from the fit with the lowest likelihood value (set to 0). Note that the fit associated with the lowest value of \mathcal{L} is in contradiction to the independent measurements of N_H and is physically unrealistic.

with the current V band photometry.

In an attempt to test the viability of our blackbody fits, we have applied the same method to a *Chandra* LETGS spectrum of the canonical SSS Cal 83, which is sufficiently well exposed and has enough spectral resolution for an atmosphere analysis (Lanz et al. 2005). We found a significantly higher luminosity and lower temperature than the atmosphere results. This confirms that blackbody fits systematically overestimate the luminosity and underestimate the temperature (see also, e.g., Greiner et al. 1991) suggesting that the actual luminosity is lower and the temperature is higher.

5. DISCUSSION

The long life time of V723 Cas is a significant departure from the typical behavior of Galactic CNe. It requires that a reservoir of hydrogen-rich material be maintained over timescales much longer than usual. For normal CNe this can be done with either a low-mass WD leading to a lower burning rate, a large amount of hydrogen left on the WD after the outburst, or inefficient mass loss mechanisms (i.e. winds, common envelope frictional drag, etc.) after outburst. With a conversion efficiency of $6 \times 10^{18} \text{ erg g}^{-1}$ and a constant luminosity of $10^{37} \text{ erg s}^{-1}$, only $3 \times 10^{-7} M_{\odot}$ of hydrogen is required to power the nova over a 12 year period, assuming no mass loss. Lower luminosities could further extend the duration of nuclear burning. Regardless of the combination of factors involved, if V723 Cas is only burning residual accreted hydrogen, it will eventually turn off.

Other systems with long outburst lifetimes such as AG Peg and RR Tel (Ness et al. 2007c) are all Symbiotic Novae which are different from CNe because they have longer orbital periods (hundreds of days) and giant secondaries with large wind mass loss rates. The WDs of these long-lived systems are probably of lower mass than those in CNe (e.g. RR Tel; Jordan et al. 1994) which allows a larger envelope of hydrogen-rich material prior to outburst. The turnoff of the hydrogen burning shell occurs on a nuclear burning timescale rather than the faster hydrogen envelope depletion timescale which includes mass loss from the ejection of previously accreted material and wind mass loss (MacDonald et al. 1985). The temperature of the WD in RR Tel is lower than the one we find for V723 Cas or for the canonical SSS Cal 83 (Jordan et al. 1994 found $T_{\text{eff}} = 142,000 \text{ K}$), again showing that Symbiotics are

different from CNe and SSSs. V723 Cas is not a Symbiotic Nova, since the orbital period is much shorter, and the companion is not a giant, which, at a distance of 2.7 kpc and $E(B-V)=0.5$ (§2.1) would lead to a higher observed magnitude than $V \sim 15$. In addition, a recent optical spectrum of V723 Cas taken during the optical minimum revealed no signature of a late-type, giant companion (Schwarz et al. in preparation). In order for the V723 Cas secondary to fill its Roche lobe, it must be a subgiant. The majority of CNe have shorter orbital periods.

There is, therefore, the interesting possibility that accretion has been re-established in the V723 Cas system and is supplying the WD with additional fuel. No signs of V723 Cas to be an intermediate polar (IP) can be found. IPs typically have strong hard X-ray components as in AM Her's and at least two periods in their optical light curves, the orbital and the spin period of the WD. In fig. 5 of Ness et al. (2007a) the X-ray spectra of V723 Cas and the IP V4743 Sgr are compared. Although V4743 Sgr is further away, the X-ray count rate at high energies is much higher, while there are no counts at high energies that can be attributed to V723 Cas. Further, a strong period of 22 min was found in the X-ray light curve of V4743 Sgr (Ness et al. 2003). The only optical period for V723 Cas seems to be the orbital period of ~ 16.6 hours (Goranskij et al. 2000). Also, Goranskij et al. (2007) report of no other period that would indicate an IP.

6. SUMMARY AND CONCLUSIONS

Although other CNe have been observed to be active for several years, V723 Cas is now confirmed to be the longest CN observed in outburst and as of December 2007 shows no indication it is turning off. While the observed count rate was variable, the spectral hardness remained unchanged. From blackbody fits we find a temperature range from 2.8×10^5 to $3.8 \times 10^5 \text{ K}$ and the luminosity greater than $5 \times 10^{36} \text{ erg s}^{-1}$. We caution that these numbers have limited physical meaning, as it is well known that blackbody fits lead to overestimated luminosities and thus underestimated temperatures (Kahabka & van den Heuvel 1997). Nevertheless, the high temperatures (especially if the numbers are underestimated) indicate that nuclear burning is still continuing. V723 Cas may be burning the remaining hydrogen left on the WD surface after the initial explosion. If so, the X-ray emission will decline once the

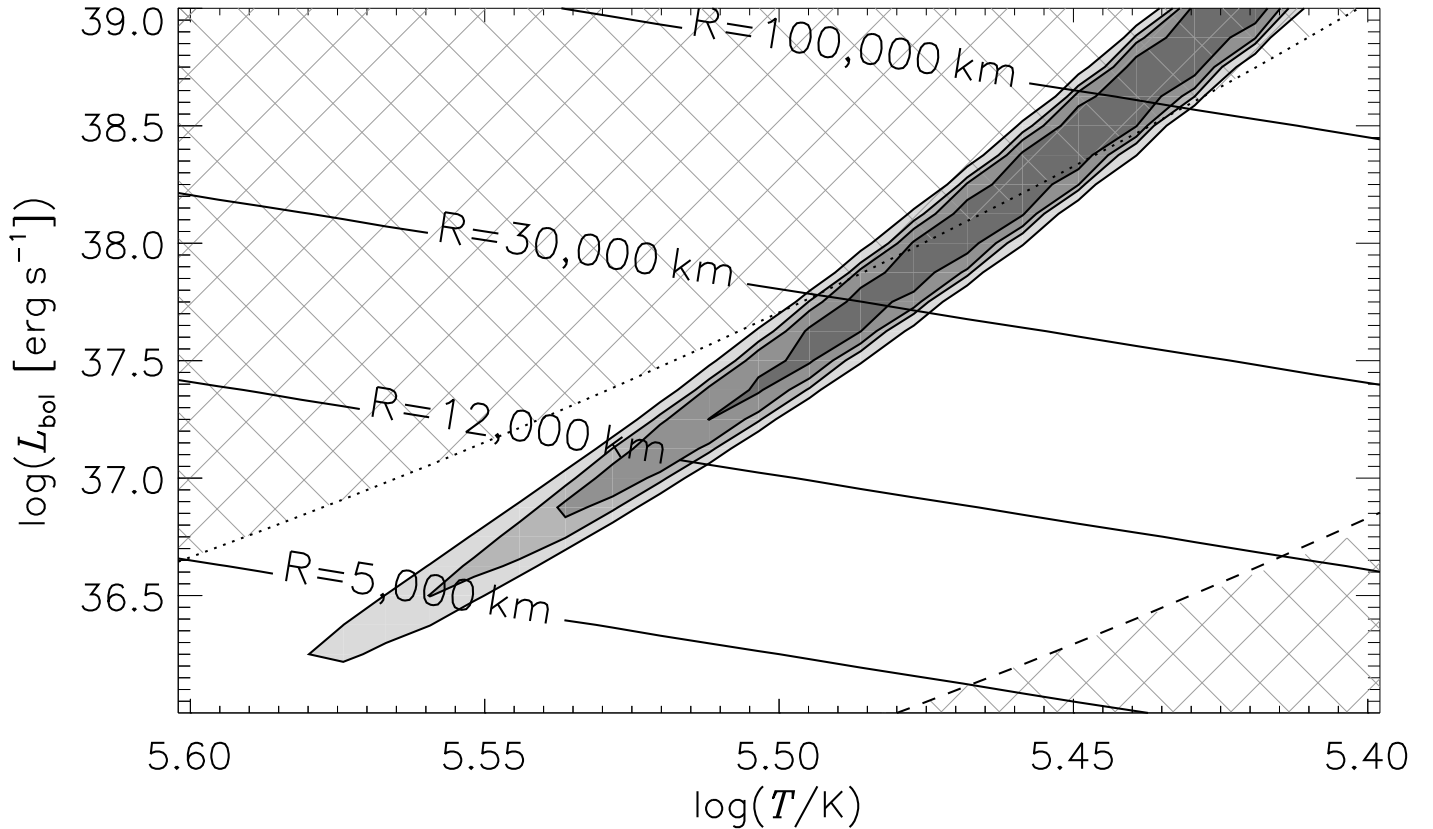


FIG. 5.— Likelihood contours for the temperature and luminosity obtained from blackbody fits to the combined XRT spectrum of V723 Cas. From dark to light shades the contours indicate the levels of 68.3%, 84.3%, 95.45%, and 99% likelihood. We draw lines of constant emitting radii R_{EM} . The highest and lowest values of N_{H} determined from independent measurements are indicated with dotted and dashed lines, respectively (values from §2.1), and we cross out regions that are inconsistent with these measurements. All fits that are consistent with the data within 99% confidence and with the independent N_{H} measurements yield luminosities below the Eddington limit.

fuel is exhausted. It is unknown when this event will happen but we plan on continuing our *Swift* monitoring program to detect a possible X-ray turn off and to further investigate the changes in the X-ray count rate.

There is also the intriguing possibility that the nova is now fed via renewed accretion similar to that observed in the prototype SSS, Cal 83. If so, V723 Cas may have evolved into a permanent SSS. Evidence that points to this possibility is the exceptional length of time in outburst and the long orbital period similar to that in Cal 83 and Cal 87. Note also that Greiner et al. (2003) found that long-period systems show shorter SSS phases than short-period systems. V723 Cas does not fit into this picture, suggesting that this is a different situation. Establishing the WD mass and determining whether accretion has re-established will assist in understanding the fate of V723 Cas. Schwarz et al. (in preparation) are presently

obtaining optical spectra during the different phases of the orbit to determine whether the V723 Cas system is dominated by an illuminated subgiant secondary, a re-established accretion disk, or some mixture of both. Any orbital variations in the lines may also be used to provide mass estimates of the system components.

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